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Effect of pressure and water content on viscosity of silicate melts

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Viscosity of silicate glasses and melts is one of the most important physical properties governing magmatic processes in Earth's mantle and crust as well as the manufacturing of glass tools. Rheology of silicate glass and melts is mainly influenced by bulk composition of the melt, temperature, dissolved volatiles (especially water content), pressure and dispersed crystals and bubbles.

We have investigated the pressure effect on viscosity in the range 10^8 to 10^{11} Pa s for melts along the join anorthite ($CaAl_2Si_2O_8$, An)–diopside ($CaMgSi_2O_6$, Di) using a parallel plate viscometer [1]. The pressure dependence of viscosity in the range 0.1–400 MPa varies from negative in the case of the polymerized An–melt to positive for depolymerised Di–melt, similar as observed in previous studies for the system albite–diopside [2]. Choosing as reference temperature the one at which the viscosity equals to 10^{10} Pa s at 200 MPa (1165 K for An and 1044 K for Di), viscosity of anorthite decreases by 0.41 Pa s and viscosity of diopside increases by 0.55 Pa s when pressure is increased from 0.1 MPa to 200 MPa. The pressure effect becomes negligible for the intermediate composition An_{50}–Di_{50}. In order to develop a general model to describe the pressure dependence of melt viscosity as a function of melt depolymerization, we have performed additional experiments on alkali silicate glasses.

Usually, the effects of temperature and water content on melt viscosity are much larger than that of pressure. The melt viscosity (range 10^1 to 10^{11} Pa s) was systematically investigated over a wide range of temperature (593 – 1523 K) and water content (0 to 4.82 wt% H_2O) for a commercial float glass (from Potters–Ballotini Company, composition in mol%: 13.7 Na_2O – 9.8 CaO – 3.3 MgO – 0.2 FeO+Fe_2O_3 – 0.1 K_2O – 0.4 Al_2O_3 – 72.5 SiO_2) using parallel plate viscometry and falling sphere experiments under pressure. Pressure effect of viscosity is expected to be negligible for

this composition with intermediate degree of melt depolymerization (molar fraction of NBO near 0.15). Adding 4.82 wt% of water to the dry melt reduces the temperature at which the viscosity of float glass equals 10^{10} Pa s by 252 K. Using our data and literature data a new model for predicting the viscosity as a function of temperature (in K) and water content (in wt %) is proposed.

[1] Schulze F. et al., 1999, Am. Min., 84, 1512-1520.

[2] Behrens H. et al., 2003, Am. Min., 88, 1351-1363.